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## REVIEW OF M. A. ROZENBLAT'S BOOK "MAGNETIC AMPLIFIERS"

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At present magnetic amplifiers are successfully replacing electronic amplifiers in many circuits, especially in amplifying dc signals. M. A. Rozenblat's monograph, Magnetic Amplifiers (Magnitnyye Usiliteli, Gosenergoizdat, 1949, 184 pp, 25 rubles) is to our knowledge the first book on this subject. It is the result of many years of study and despite its brevity and minor shortcomings, offers a sufficiently full statement of the working principles of various types of amplifiers and analyzes the basic circuits by the author's own method of calculation.

The book contains seven chapters. Chapter 1 treats the physical bases of magnetic amplifier performance. The statement starts with a graph illustrating the increase of alternating current with an increase in the dc component of magnetic induction. Next, we detect the presence of the even B and H harmonics under magnetization. The confusion frequently encountered on the possibility of magnetic "rectification" is noted, and various definitions of the average magnetic permeability are suggested. This chapter also provides an experimental basis for the remarkable fact that even harmonics of the field intensity increase the magnetizing action produced by a direct current. The author shows that utilization of the even harmonics of the field intensity improves magnetic amplifier characteristics. He compares the merits and special features of ac windings connected in series and in parallel.

It is not clear why the characteristics of E4A sheet steel and other steels and the use of these characteristics in amplifier design are included in this chapter. Moreover, the author does not even mention the well-known family of characteristics B = f (H) at different values of constant field intensity



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($H_0$ = const), although these curves are useful in examining the physical bases of amplifier performance. In fact, only six pages in the whole book are devoted to the physical fundamentals of amplifier performance, which is obviously insufficient. Moreover, the coverage of these fundamentals is unsystematic. For example, the case of an ideal choke coil magnetized by a direct current, although it is of value to illustrate physical fundamentals, appears in the second chapter instead of the first.

Chapter II deals with calculating choke magnetic amplifiers without feedback. First, the author established the conditions for maximum output of a choke amplifier and utilizes the results for computations. By the proposed method of computation, he determines optimum parameters which ensure maximum output at the highest amplification factor, i. e., minimum drain of control power.

This method differs from similar methods of calculating choke magnetic amplifiers only by using the experimental curves of magnetic permeability in dependence on $B_m$ and $H_0$ instead of the conventional characteristics $B_m = f(H)$ for different values of $H_0$ = const. But the author deserves credit for trying to develop a computation method which would make it possible to establish the optimum parameter for amplifiers.

Rozenblat unfortunately does not make any comparison between this method of calculating choke-coil amplifiers and other methods. In addition, he starts with a number of assumptions (currents and voltages are considered sinusoidal, leakage negligible, e.c.), but he does not consider it necessary to formulate these assumptions clearly and then show that such assumptions are possible on the basis of experimental data. This procedure would have clarified the author's statement that the calculated value for the magnetizing field intensity must be increased on an average by 10-20%.

Chapter II discusses the selection of cores for magnetic amplifiers but fails to mention the most effective relations between sizes of core laminations. Now that magnetic amplifiers are so widely used, it would seem desirable to develop special types of cores for them instead of depending on standard transformer types.

Too little attention is paid to toroidal cores. A comparison should be drawn between two amplifiers with identical output parameters, where, for example, one has a three-legged and the other a toroidal core. Then, the effect of the absence of air gaps and low leakage in the toroidal core on the parameters of the amplifier employing it (the data on p 72 is insufficient) could be shown. Since special machines for winding toroids are available, the advantages or disadvantages of amplifiers with toroidal cores should be made clear.

The discussion of phase bridges (p 45) seems superfluous. If this use of choke coils with magnetization is pertinent, it should be treated in the chapter on applications of magnetic amplifiers.

Chapter III examines the basic circuits for push-pull magnetic amplifiers, i.e., amplifiers reacting to the sign of the control signal. It describes the principle of operation of the three basic types of push-pull amplifiers -- differential, bridge, and transformer types. The author then shows that the output power of these three types can be expressed by the same formula. He pays particular attention to the case of a matched load, i.e., one for which the amplifier will have maximum output power for a given signal.

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Developing the calculation methods covered in Chapter II in a more complex form, the author proposes methods for calculating push-pull magnetic amplifiers with optimum parameters. He calculates two cases: an amplifier for maximum power and an amplifier with a maximum amplification factor for weak signals.

The method is fairly cumbersome, because first it is necessary to plot complex experimental curves for magnetic permeability and to obtain a number of curves for certain auxiliary coefficients. However, if the latter curves are available, the technique of the calculations becomes very simple and does not require much time. The auxiliary characteristics calculated for transformer steel and molybdenum permalloy (cited in Figures 33-35) greatly facilitate the task of calculating push-pull magnetic amplifiers. But if the characteristics of the magnetic material to be employed differ greatly from the characteristics of the magnetic materials (Figures 4 and 13), for which the book gives the auxiliary characteristics, it is necessary to carry out long preliminary calculations each time. The author presents a method of determining the load current for intermediate values of the control current after calculating the amplifier for maximum power output and illustrates it with a design for a push-pull magnetic amplifier, demonstrating the agreement between calculated and experimental data.

In Chapter III, as in Chapter II, there is no comparative analysis of the two methods of calculation. The chapter ends with a discussion of various magnetic voltage amplifiers. It is shown clearly that if a voltage amplifier operates with a finite load, there will be a quite definite optimum value for the number of secondary winding turns at which the voltage amplification factor will be a maximum.

In cases where it is possible to consider that the secondary (output) circuit of the amplifier is open, the author suggests the use of I. Ya. Lekhtman's method of calculation and sets forth its basic principles.

Chapter IV discusses magnetic amplifiers with feedback, and shows that a positive feedback is one of the basic methods of raising the amplification factor and lowering the sensitivity threshold. Choke amplifier characteristics are given for different feedback factors. Different push-pull amplifier circuits with positive feedback are examined with the load in the ac or dc circuits. In addition to describing the operating principles of the circuits, Rozenblat makes a comparative analysis of their advantages and disadvantages and recommends the use of a certain circuit in different practical cases.

The section on calculation of magnetic amplifiers with positive feedback proposes a simplified procedure permitting a first approximation of the basic amplifier parameters. The method for calculating such amplifiers has not been developed thoroughly, and the simplified method proposed is a step in the right direction. Unfortunately, no practical examples of this procedure are given, and calculated data are not compared with experimental material.

Rozenblat defines positive feedback as feedback which produces a supplementary magnetizing field which strengthens the signal field, while a negative feedback is one which produces a magnetic field oppositely directed to the control magnetic field. More precisely, the feedback should be called positive if it acts on the output parameter of a magnetic amplifier in the same direction as the control signal.

With reference to the feedback factor, Rozenblat should have pointed out the great effect of the load inductance, e.g., in a choke amplifier with positive feedback with the load in the dc circuit, and should have illustrated

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this effect with some characteristics. If the effect of the load inductance is not taken into account in selecting the number of feedback turns, completely unexpected results may be obtained. Even when the feedback factor is less than unity, the amplifier may become overexcited and operate as a relay when the load is inductive. The very short remark on page 119 to the effect that the ripple ratio of the rectified alternating current must be taken into consideration is far from sufficient.

Chapter V examines transient processes in magnetic amplifiers. After a detailed analysis of lag in magnetic amplifiers, the author points out a number of factors influencing lag and gives a quantitative evaluation of the degree of influence exerted by these factors. Many articles in journals have pointed out that lag in the ac circuit of a magnetic amplifier can be disregarded in most cases, but Rozenblat is the only one who has presented a positive mathematical proof of this experimental fact.

The amplifier lag is due mainly to the lag of the alternating current behind the voltage at the amplifier input. Experimental data has shown that the control circuit may be considered linear for most types of magnetic amplifiers since the dc component of magnetic flux in the amplifier cores is linearly dependent on the magnetizing mmf. On the basis of this assumption, the author examines the lag of magnetic amplifiers with and without feedback. Furthermore, he sets up a general equation for magnetic amplifiers which permits analytical study of an entire automatic regulation circuit as a whole if it contains magnetic amplifiers. Experimental data confirming the author's method of calculating lag is given at the end of the chapter.

The problem of lag in magnetic amplifiers is extremely important since in many cases excessive lag may make it impossible to use an otherwise suitable amplifier in a given control circuit. Consequently, the material presented in this chapter is very valuable. It is regrettable, however, that the author did not discuss his experimental work more fully. For instance, he does not give even one example of a choke amplifier where the dependence of the ac component of the magnetic flux on the control current is not linear, although he indicates the existence of such cases. He does not indicate which type of amplifier is desirable from the viewpoint of lag for a given amplification factor, nor does he give any data on the lag of a magnetic amplifier operating as a relay.

Chapter VI gives some typical applications of magnetic amplifiers, but more attention should have been paid to this subject in a book of this type. Among practicing engineers, especially those accustomed to employing electronic equipment in automatic control circuits, there is still a certain amount of prejudice against magnetic amplifiers, founded largely on inadequate understanding of the principles of their design and operation. Rozenblat's book should do much to remove this prejudice. However, for this very reason, the book should have treated applications of magnetic amplifiers in more detail, emphasizing and illustrating their use in conjunction with electronic equipment. Magnetic amplifiers can simultaneously amplify and convert dc signals to ac signals which can be readily amplified by electronic amplifiers.

Chapter VII discusses magnetically saturated magnetic probes. In a book of such restricted size, the absence of literature on this subject is not an adequate excuse for including this topic, which has no direct connection with magnetic amplifiers.

Despite careful editing, there are a number of minor errors in the book, but it is well written and will prove of great value to a wide circle of readers.

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